Evaluation of the Lumbar Kinematic Measures That Most Consistently Characterize Lumbar Muscle Activation Patterns During Trunk Flexion: A Cross-Sectional Study

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Abstract

Objective: The purpose of this study was to determine which kinematic measure most consistently determined onset and cessation of the flexion-relaxation response.

Methods: The study was a cross-sectional design in a laboratory setting in which 20 asymptomatic university-aged (19.8-33.3 years old) participants were tested. Muscle activation was measured for the lumbar erector spinae, and 3-dimensional motion was recorded. Flexion-relaxation onset and cessation occurrences were determined for 10 standing maximum voluntary flexion trials. The lumbar and trunk angles at both events were expressed as unnormalized (°) and normalized (%Max: percentage of maximum voluntary flexion) measures. Intraclass correlation coefficients and coefficients of variation were calculated to determine within- and between-participant reliability, respectively.

Results: Mean (SD) unnormalized flexion-relaxation angles ranged from 46.28° (11.63) (lumbar onset) to 108.10° (12.26) (trunk cessation), whereas normalized angles ranged from 71.31%Max (16.44) (trunk onset) to 94.83%Max (lumbar cessation). Intraclass correlation coefficients ranged from 0.905 (normalized lumbar, left side, onset) to 0.995 (unnormalized lumbar, both sides, cessation). Coefficients of variation ranged from 3.56% (normalized lumbar, right side, cessation) to 26.02% (unnormalized trunk, left side, onset).

Conclusions: The data suggest that, for asymptomatic individuals, unnormalized and normalized lumbar kinematics most consistently characterized flexion-relaxation angles within and between participants, respectively. Lumbar measures may be preferential when the flexion-relaxation response is investigated in future clinical and biomechanical studies. (J Manipulative Physiol Ther 2015;38:44-50)

Key Indexing Terms: *Biomechanics; Kinematics; Low Back Pain; Electromyography; Spine*

The lumbar flexion-relaxation phenomenon (FRP) describes an abrupt and substantial decrease of myoelectric activity in the lumbar erector spinae (LES) muscles at or before maximum voluntary flexion of the trunk during sagittal flexion from the upright position.[1–3] It is generally accepted that the lumbar FRP is characteristic in an asymptomatic population[4,5] and that the 3 phases of the movement (flexion movement, static maximum voluntary flexion, and extension movement) can be clearly delineated. Conversely, low back pain (LBP) patients exhibit an altered or absent FRP response[6–9] in which the distinct phases of FRP become less distinguishable. The exact mechanisms underlying FRP are still debated in the literature. Various explanations have been proposed, including a load transfer from the superficial erector spinae muscles to the passive tissues[1–4,10] or to the deep erector spinae muscles[11] near the end range of full flexion. It has been suggested that a later FRP onset (and earlier cessation) or a complete lack thereof may indicate the presence of a protective mechanism of the neuromuscular system[7] or pain inhibition.[8] According to these findings, prolonged LES activity during the maximum flexion movement (and a consequent later FRP onset and earlier FRP cessation) is elicited, which increases protection during movements that may cause pain in the passive spinal structures.

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Since Floyd and Silver[1] coined the term *flexion-relaxation*, numerous studies have quantified the kinematic measures at which LES relaxation occurs,[2–4,7–10,12–16] as well as the lumbopelvic strategies used during trunk flexion and extension.[12,17–19] Previous studies have used lumbar or trunk flexion angles, reported either as unnormalized angles (°) or as a percentage of maximum voluntary flexion (%Max), to quantify the onset and cessation of LES flexion-relaxation. However, methodological differences in FRP identification, such as the selection of an FRP threshold criterion,[20] have made it difficult to compare results between studies and have led to wide ranges of FRP onset and cessation measures reported in the literature, expressed as both unnormalized and normalized values. Consequently, the challenge of establishing normative data by determining which angle measure characterizes FRP most consistently during trunk flexion remains.

Trunk angles are generally determined by tracking the angle of the segment defined by the shoulders and the hips,[2–4,14] whereas the quantification of lumbar spine angles involves tracking the motion of the T_{12} or L_1 vertebra relative to the L_5 vertebra or the sacrum.[16] Past studies have established that, in individuals without LBP, FRP occurs near the end range of trunk and lumbar flexion. Unnormalized FRP trunk onset angles have ranged from 52.2°[15] to 89.9°,[12] whereas normalized trunk angles have ranged from 62%Max[7] to 90%Max.[9] With regard to the unnormalized lumbar flexion angles, FRP onset has been documented as occurring between 25°[10] and 58.8°,[8] whereas FRP onset expressed as a percentage of maximum voluntary lumbar flexion has ranged from 69%Max[16] to 93%Max.[13]

Although various measures of FRP onset and cessation angles have been reported, the measure providing the most consistent kinematic results remains to be identified. Therefore, the purpose of this study was to determine whether (*a*) the trunk angle or the lumbar angle and (*b*) unnormalized (°) or normalized (%Max) measures yielded the most consistent FRP onset and cessation measures during maximum voluntary trunk flexion. It was hypothesized that normalized measures would demonstrate greater consistency than the unnormalized measures, as normalizing accounts for interpersonal differences in maximum range of motion (ROM). Furthermore, it was hypothesized that lumbar measures would exhibit greater consistency than the trunk measures, as this measure better represents the positioning of the localized region in which FRP is taking place, as opposed to a global measure that is more representative of whole body posture (ie, trunk angle).

Methods

Participants

This study used 20 right-hand–dominant participants (10 male, 10 female) who were free of back pain and did not seek treatment and/or miss work or school because of back pain for at least 1 year before the collection of the data. Participants were recruited from the York University population between August 2012 and November 2012, ranged in age from 19.8 years to 33.3 years, and were recreationally active. The mean (SD) age, weight, and height were 23.6 years (2.9), 60.79 kg (5.60), and 1.67 m (0.06), respectively, for the females and 24.4 years (4.2), 77.28 kg (9.90), and 1.79 m (0.05), respectively, for the males. The Office of Research Ethics of York University approved all procedures, and informed, written consent was obtained from all participants before data collection.

Instrumentation

Activity of the left and right LES was recorded using surface electromyography (EMG). The electrode sites were shaved and swabbed with rubbing alcohol before the application of 2 pairs of disposable Ag-AgCl electrodes (Ambu Blue Sensor N, Ambu A/S, Ballerup, Denmark). Electrodes were placed 4 cm bilaterally to the third lumbar (L_3) spinous process[21,22] with a 2-cm interelectrode spacing. The EMG signals were differentially amplified (frequency response, 10-1000 Hz; common mode rejection, 115 dB at 60 Hz; input impedance, 10 GΩ; model AMT-8, Bortec, Calgary, Alberta, Canada) and sampled at 2400 Hz (Vicon Systems Ltd, Oxford, UK).

Kinematic data were recorded by a 7-camera Vicon MX motion capture system (Vicon Systems Ltd). Each participant was instrumented with 59 passive reflective markers. Clusters of 5 markers were applied at the level of the seventh cervical vertebra (C_7); the third, sixth, ninth, and 12th thoracic vertebrae (T_3, T_6, T_9, T_{12}); and the fifth lumbar vertebra (L_5). The remaining markers were placed on the head (5), acromia (2), trunk (2: sternum and T_{10} vertebra), pelvis (4: iliac crests, anterior superior iliac spines), greater trochanters (2), and legs (14: thighs, knees, and ankles). Kinematic data were sampled at 50 Hz.

Procedures

Following electrode application, participants then performed 3 manually resisted isometric back extension trials to elicit the maximum voluntary contraction (MVC) level for the trunk extensors.[23] A sufficient rest period (5 minutes) was given between the trials to minimize the effects of muscle fatigue. For each muscle, the maximum EMG signal of any of the 3 trials was designated as the MVC and used to normalize the subsequent EMG data (see "Data Processing").

Markers were then applied before conducting a 10-second static kinematic calibration trial ("T-pose"). This was followed by a total of 20 experimental trials performed in a randomized order. Participants performed 10 upright standing trials to establish a reference position for trunk and lumbar flexion. Each of these trials lasted 10 seconds with the head in

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